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Rural Access to Industry 4.0: Barriers from the Infrastructure Planning Front Lines

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Abstract

Many rural communities lack adequate broadband infrastructure, which limits the economic development potential in these regions. They are not able to attract new businesses, and established businesses are unable to use tools and services that require high-speed internet. Broadband access is a requirement for the Internet of Things, robotics, and big data, which are part of Industry 4.0 and the future economy. Such technological advances are not only transforming the manufacturing environments and the service industry, but also finding applications in the food supply chain, such as precision agriculture. In this study, we conducted 17 semi-structured interviews (11 reported here) with Missouri Regional Planning Commission (RPC) directors and experienced infrastructure planners to identify barriers for the deployment of broadband infrastructure in rural Missouri. Systematic qualitative analysis was conducted to identify key themes based on barriers previously identified in the literature. Participants reported that the top barriers are the return on investment and financing of rural broadband projects. The literature tends to be dominated by technology solutions, which received the least number of mentions as a barrier in the interviews.

Keywords

Rural, broadband, strategic planning, infrastructure, economic development

1. Introduction

Closing the digital divide is the #1 strategic goal of the Federal Communications Commission (FCC) in the U.S. government agency's 2018-2022 Strategic Plan [1]. Consequently, one of the key targets is expanding the deployment of broadband infrastructure in rural areas. The Missouri Office of Broadband Development reports that 1.26 million Missourians (20% of the state population) do not have access to high-speed internet, including 1.04 million in rural areas [2]. Broadband internet is an essential tool for economic activity, and this is no different in rural communities [3]–[6]. In a U.S. nationwide study, Whitacre et al. [6] report that the adoption of broadband in rural areas positively impacted income growth during 2001-2010 while negatively influencing unemployment growth. Pant & Odame [7] found that broadband constitutes an essential tool for enabling the diversification of products and services provided by rural small businesses. Broadband access is a requirement for the Internet of Things, robotics, Big Data, and Artificial Intelligence, which are part of Industry 4.0 [8, 9]. Such technological advances are not only transforming the manufacturing environments and the service industry but also finding applications in the food supply chain, such as precision agriculture [9]. Canfield et al. identified six barriers to broadband infrastructure investment in a state-of-the-art matrix (SAM) analysis based on a review of 30 papers: technology, hardware costs, regulatory, financing, management, and adoption. Overall, management and adoption were less represented in the literature [10].

In the present study, a series of 17 semi-structured interviews were conducted with experienced infrastructure planners regarding broadband infrastructure deployment in rural communities. The primary research questions were:

- (1) What are the barriers to the deployment of broadband infrastructure in rural communities?
- (2) How does the prevalence of observed barriers compare to the prevalence in the literature?

2. Methods

2.1 Participants

In Missouri, Regional Planning Commissions (RPCs) support their municipal and county members in economic planning and development via initiatives related to infrastructure needs, such as transportation, water, and wastewater [11]. We conducted semi-structured interviews with 16 of the 19 (84.2%) Missouri RPCs and one statewide official. As described in Figure 1, results from 10 of the interviews are reported here, which includes 3 Northwest, 2 Northeast, 3 Southeast, and 2 Southwest Missouri planners. Both university Institutional Review Boards approved the study, and all participants provided informed consent.

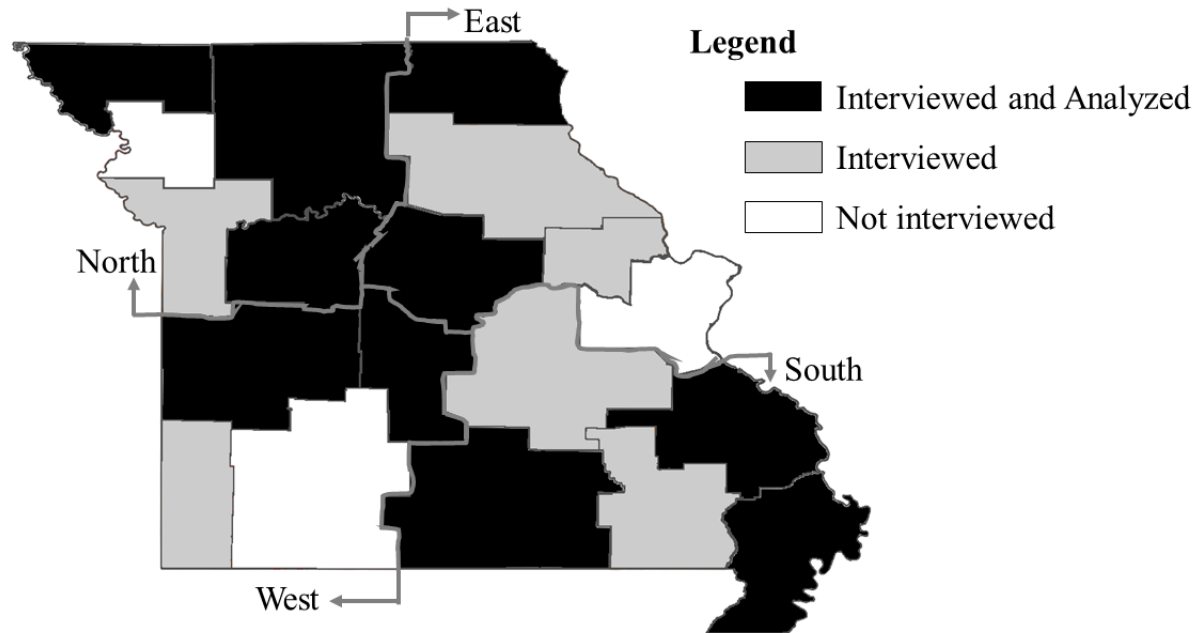


Figure 1: Map of Missouri showing regions where infrastructure planners were interviewed (gray and black) and analyzed for this study (black).

2.2 Procedure and Analysis

The interviews were divided into three main sections:

- (1) Barriers for rural broadband infrastructure deployment
Example: What are the main barriers to addressing internet access?
- (2) Decision-making process for successful and unsuccessful broadband infrastructure investments
Example: What risks were people worried about?
- (3) Opportunities to increase cost-efficiency for infrastructure deployment
Example: What ideas do you have to improve efficiency and reduce costs for government-funded infrastructure projects?

The interview protocol is available at: <https://osf.io/h5qx2>. As described in Figure 2, we performed a rigorous systematic qualitative analysis by coding key themes in the interviews using MAXQDA, a qualitative research software. The key themes were determined based on (1) predetermined barrier categories from the literature in Canfield et al. [10] and (2) concepts that emerged from the interviews themselves, consistent with the grounded theory approach [12]. Each interview was coded using a consensus technique where 2-3 coders independently coded an interview and then reviewed the interview together to generate a consensus coding and write a 2-3 page memo summarizing the main ideas. An auditor who did not participate in the coding then reviewed the consensus coding to ensure accuracy and consistency across all interviews [13].

Lastly, we tallied which categories were considered barriers by each participant and compared the prevalence to the literature, as reported by Canfield et al. [10].

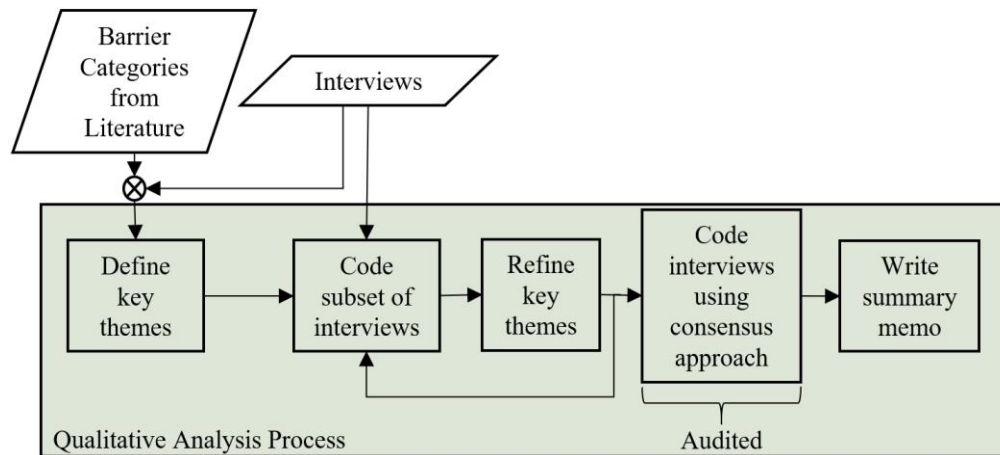


Figure 2: Qualitative analysis process using a consensus approach

3. Results

RPCs consider broadband to be critical infrastructure for economic development in rural communities. Attracting new businesses and enterprises without broadband access is very challenging. Broadband service also provides expansion opportunities for existing businesses, including farming operations, as explained below:

“I do put internet access under economic development. But having the appropriate internet access is just extremely vital at this juncture to be able to support small business development, which is the true driver for economic development in rural America. But also even larger business attraction. That’s pretty much a minimum requirement these days. When we look at the status of the agricultural sector in our overall economic base, that’s becoming a very critical element in order to take advantage of all modern agricultural techniques.” [participant 57]

Broadband access provides many benefits, such as education and telemedicine, but RPCs are most interested in it as an economic development tool to achieve their mission.

3.1 Hardware Costs

In general, participants identified the main barrier for the deployment of broadband infrastructure in rural communities to be the return on investment (ROI). Low population density, shifting demographics, and high poverty rates make rural areas unappealing for private investment [14]. As described below, infrastructure planners are sympathetic:

“I think it’s when you’ve got 10,000 people over hundreds of square miles and that population is currently dropping, I just don’t know that it makes a lot of economic business sense to be investing millions of dollars to get high-speed access to some of those counties. I don’t really know. [...] I think that’s probably the biggest barrier, there’s a need for it, but it’s going to be difficult to get that need paid for.” [participant 42]

3.2 Financing/Funding

Government funding is required to stimulate private entities to invest in rural broadband infrastructure due to low market incentives to take on the risk of a large infrastructure project with uncertain adoption rates. Even then, some private entities have concerns about meeting the requirements associated with federal funding:

“It’s hard to convince a private sector company to move forward with a federal funding application because they’re concerned about what strings are attached to that federal funding.” [participant 10]

Another concern is that some of the federal funding assistance is in the form of loans:

“I will say that part of the problem with the USDA dollars is that most of the money does not come in the form of a grant, it’s partially grant and then it’s also accompanied with loan. And so for these electrical co-ops, the fact that part of the funding comes in the way of a loan obviously makes the cost-benefit ratio steeper for them.” [participant 99]

3.3 Regulatory/Law

Participants varied in terms of their knowledge of the regulatory environment for broadband. There is a Missouri state law that “prohibits local governments from selling or leasing telecommunications services”, which prevents potential municipal actors from entering the market [15]. Given that RPCs exist to serve local governments, this limits their engagement:

“Potentially, some of the regulations that don’t allow cities to be the providers of internet service. That’s one reason we haven’t got into as much as I think we’d like to is that’s typically who we work through are the cities and counties. If those cities and counties can take it on themselves, the ones that really need it, I think there might be more of them. I think that is definitely a barrier.” [participant 14]

In some cases, regulations related to easements and right-of-way are limited to a specific utility, such as energy. As a result, broadband services are not allowed to piggyback on that existing infrastructure, including poles:

“You may have an idea of where you want the infrastructure to go, but getting the easements, the right-of-way, the planning ... It’s not considered a utility like electric and gas is, oftentimes, so we can’t even string on the same poles if we want to, or in the same area without going back and getting easements and stuff. I know they’ve been working on that within the state, within the federal system.” [participant 71]

3.4 Adoption

Some infrastructure planners did not perceive the adoption of broadband technology as a barrier because most citizens recognize the need for the technology. However, many rural populations are sensitive to cost, and affordability could be a barrier:

“I think most people accept that broadband is what we need, in terms of being a viable solution for not only economic development, but for education and health these days. I think it’s just a matter of affordability. Can they afford what they need at their home?” [participant 71]

Also, aging populations in rural areas may be less interested in adopting broadband service, increasing uncertainty:

“[...] lot of folks still don’t have a computer at home. [...] thus, no need for the broadband fiber to go in front of that house and pass up \$50 a month, because that person doesn’t want it, doesn’t need it, doesn’t care about it, doesn’t understand it.” [participant 88]

3.5 Management

Management is not perceived as a barrier for the deployment of rural broadband infrastructure, largely because most of the decision-making happens in the private sector. This has reduced engagement of public sector actors, limiting their knowledge and experience:

“The comparison that’s often made and they’re kind of right is that this [broadband] is the same problem we had with rural electric when electricity first started to be deployed. But it’s just a very different problem otherwise. This is more private. It’s been in the private sector versus the public sector for so long that I don’t think the public sector knows how to approach it. I can’t call up another RPC and say, how’d you guys help them get ... You know what I mean? Because they haven’t done it. [...] I know in the Northeast there’s been a couple communities that have been successful. I know RPCs assisted, so I’m not saying they’re not doing anything. I’m just saying, it’s a new problem, and it’s been given off to the private sector for so long, we don’t know how to approach it.” [participant 10]

On the other hand, some participants see management as a barrier:

“I could see it [management] as a barrier because there’s no real connection between all of the efforts. Everyone’s doing their own thing.” [participant 91]

3.6 Technology

Technologies vary in terms of effectiveness and cost. Wireless technologies are scalable. However, as described below, the hilly terrain in rural Missouri is a major challenge for wireless broadband to represent a viable technology:

“Because the hills and hollers; you almost have to be... It almost would have to be hard-wired to get the guy, or the lady, or the household, down by the river, because your signals will go across the top of the hills, and it doesn’t come down. You’d have to have high towers. If it’s going to be wireless, it’d have to be high up to get down to the valleys, because people who live down in the valleys, they can’t get it. There’s blind spots and dark spots all over this region.” [participant 88]

In addition, wireless high-speed internet does not provide the same economic development possibilities as wired options. As described below, fiber optic is the best solution for industrial applications, but it is also the most expensive:

“So obviously fiber’s going to be about the best that you have to work with, but that’s the most expensive to get here. So again, that cost becomes a problem, so we don’t have a lot of fiber. We have a lot of DSL [Digital Subscriber Line]. [...] Right now, we have a lot of small telcos moving in wanting to do fiber backbones but then do primarily wireless service. [...] It’s not good enough service, it’s not going to give you the kind of upload speeds you need for certain business. Again, that doesn’t help industry.” [participant 10]

3.7 Comparison to Prevalence of Barriers in the Literature

As described in Table 1, infrastructure planners identified the low ROI, which is related to hardware costs and financing, as the main barrier for broadband deployment in rural communities. This is consistent with the academic literature, where hardware costs and financing were the second and third most prevalent barrier discussed in the literature [10].

In general, infrastructure planners did not consider existing technology to be a barrier to the deployment of rural broadband infrastructure. However, this barrier was most frequently discussed in the literature. This is likely related to the role of research & development (R&D), which tends to focus on technology rather than systems solutions. It is possible for a technology solution to directly address the ROI challenges.

A slight majority of infrastructure planners considered laws and regulations to be a barrier (55%). This prevalence is similar to the literature review, where 57% of selected papers discussed regulatory barriers. However, in terms of ranking, regulatory barriers received more attention (tied for 2nd) in the literature than the interviews. This may be because of the specific regulatory context in Missouri, which limits public sector engagement.

In both the interviews and literature, adoption and management received less attention as barriers. It is unclear if this is due to perceptions that these are not barriers, or because these barriers are seen as less important to address than others. Adoption and management challenges tend to increase uncertainty about the ROI. As a result, addressing these barriers could contribute to addressing the primary barrier of ROI.

Table 1: Comparison of mentions in interviews versus the literature [10]

Barrier Category	Mentions in	
	Interviews (%)	Articles (%)
Hardware Costs	11 (100%)	17 (57%)
Financing/Funding	11 (100%)	16 (53%)
Regulatory/Legal	6 (55%)	17 (57%)
Adoption	6 (55%)	7 (23%)
Management	5 (46%)	10 (33%)
Technology	4 (36%)	19 (63%)

4. Conclusions

In summary, the ROI, in terms of hardware cost and financing, for private entities was the primary barrier for the deployment of rural broadband infrastructure identified in the interviews. This is consistent with the literature, which frequently cites ROI as a major barrier [10].

RPCs have vast experience planning and managing infrastructure projects for other infrastructure needs (e.g., transportation, water, wastewater, etc.), which can be leveraged to improve and streamline broadband infrastructure planning projects. They have vast experience working with government funding processes across federal and state agencies. In addition, they have the convening power to bring key players to the conversation table. RPCs are well-positioned to support broadband infrastructure deployment in rural communities.

Infrastructure planners may benefit from better tools to manage coordination and investment decisions, such as data collection apps, benefit-cost models, risk analysis, template policies, and information-sharing mechanisms. Although management was not identified as a major barrier in the interviews or literature, infrastructure planners acknowledge that there has been limited public sector involvement because most broadband investment decisions are made by private industry.

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